2016-02

CRUSER News / Issue 60 / February 2016

Monterey, California: Naval Postgraduate School

http://hdl.handle.net/10945/48037

Issue 60 February 2016

CRUSER · NEWS

Consortium for Robotics and Unmanned Systems Education and Research

From Technical to Ethical...From Concept Generation to Experimentation

Contents

Joint UAV Swarming Integration Quick Reaction Test
F Patrick Filbert

Mitigating Cosite Interference
Doug King

Student Corner
Courtney A. Guy

Drone Detection at the Rose Bowl
The Aerospace Corporation

Librarian Corner
Greta Marlatt

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Joint Unmanned Aerial Vehicle (UAV) Swarming Integration (JUSI) Quick Reaction Test (QRT)

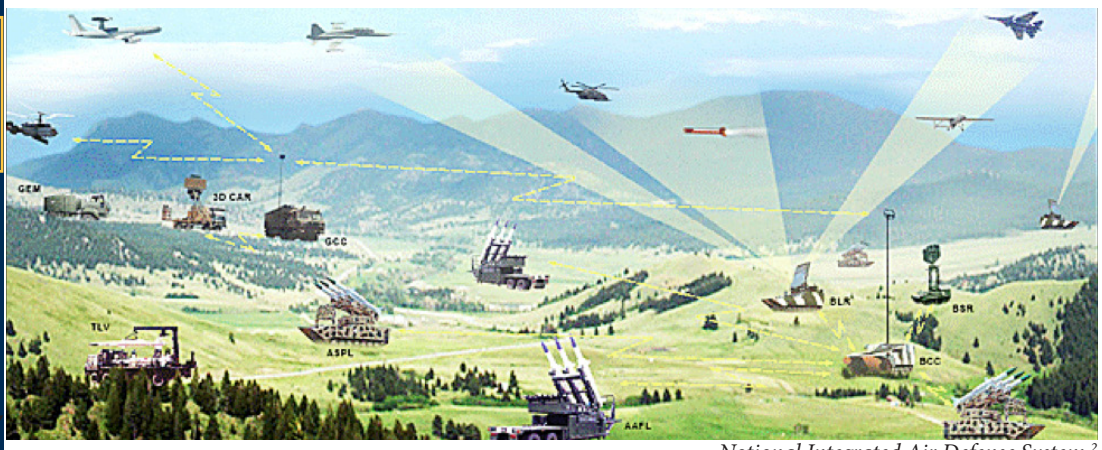
by F. Patrick Filbert, Subject Matter Analyst-UAS, frederic.filbert.ctr@pacom.mil

As technology improves, so does the capacity to expand a defensive perimeter to ever increasing ranges both horizontally and vertically. Identifying ways to penetrate this perimeter with assets and capabilities that do not require ever more expensive solutions requires creative use of current and emerging technological advances. Potential adversaries understand the United States (U.S.) is extremely technologically advanced with its warfighting systems. This requires a thinking enemy to develop ways to keep America's advanced systems outside their sphere of influence; specifically, to both deny and create an inability to gain access to specific areas of operation. In the current vernacular, this is called creating an anti-access/area denial (A2/AD) environment which has, as its backbone, advanced integrated air defense systems (IADS).

A Bit of History

Being able to provide a "layered" offensive capability with manned kinetic/non-kinetic payload armed aircraft has been done for some time. One example is how a joint Army-Air Force helicopter team (Task Force Normandy: comprised of U.S. Air Force (AF) MH-53J/PAVE LOW III and Army AH-64/APACHE attack helicopters) blinded Iraqi IADS early warning radars with non-kinetic electronic attack (PAVE LOW IIIs) and destroyed the radars (APACHES) with kinetic weapon's strikes (i.e., HELLFIRE missile, HYDRA rocket, and 25mm cannon fire) in the opening minutes of Operation Desert Storm to allow follow-on USAF strike aircraft access through coverage "holes" in Iraqi IADS to attack key targets further into Iraq[1]. Similarly, future use of an advanced wave of unmanned aircraft systems (UAS) equipped with electronic warfare (EW) payloads leading a subsequent wave of attacking aircraft from carrier strike groups is one potential way to enter and counter a potential adversary's A2/AD environment.

However, while emerging EW payload testing on UAS is occurring, mating electronic attack (EA) payloads onto a coordinated semi- or fully-autonomous swarm of smaller unmanned aircraft (UA) is still an emergent test environment effort. However, once such capabilities mature, being able to employ them requires that a foundational concept be in place. The Joint Unmanned Aerial Vehicle (UAV) Swarming Integration (JUSI) Quick Reaction Test (QRT) was directed on February 27, 2015 by the Deputy Director, Air Warfare under the authority of the Office of the Secretary of Defense, Director, Operational Test and Evaluation to address such a foundational approach.



Notional Integrated Air Defense System [2]

Director's Corner by Ray Buettner, CRUSER Director

As most of you know, CRUSER is the SECNAV's Consortium funded by the Office of Naval Research at the Naval Postgraduate School. The NPS founders are Assistant Professor Tim Chung, Professor Jeff Kline, and myself. Tim and I drafted the first proposals and worked with the Undersecretary of the Navy (then Mr. Robert O. Work) to get CRUSER off the ground. Jeff Kline served as the first Director and created a process that tightly couples CRUSER activities to the NPS educational process while also forging strong connections to big Navy that no one else could have created.

Tim has been our academic star but also has stood in wherever needed. I have a very distinct memory of sitting in front of a white board covered with potential names and their corresponding acronyms with one rapidly becoming my favorite – CRUSR. So while you would be quite correct to notice that there is no "I" in CRUSER you would also notice that there is now an "E" for Education. Among his many accomplishments Tim put the "E" in CRUSER! In addition to sharing credit for the defining of the coolest acronym in the Navy today (just my opinion – read the disclaimer!) Tim has embedded robotics into all of his courses, assisted other faculty in the incorporation of robotics into their course work, mentored high school and college interns, advised numerous thesis students and served as our prime connector to external robotics programs at the Nation's finest universities. He has reviewed proposals for DARPA, ONR and even NSF, published academic papers, presented at academic conferences and all the while assisted first Jeff, then I, in the administration of what is now $4 million dollar program. Oh, and along the way he led the research team that set and holds, the record for creating and flying (outside the lab!) the largest fully autonomous aerial swarm.

Tim is moving on to DARPA where he will continue to be part of the CRUSER community and will enable even greater achievements for the Department of Defense and the Nation. We wish Tim the best of luck in his new role and look forward to his continued participation in the CRUSER community!

The JUSI QRT was established under the Director of Operational Test and Evaluation's Joint Test and Evaluation Program on July 29, 2015. It is co-located with U.S. Pacific Command's (USPACOM) J8 Resources and Assessment Directorate, Camp H.M. Smith, Oahu, Hawaii. The JUSI QRT reports to the AF Joint Test Program Office (AFJO), Nellis Air Force Base, Nevada and receives support from USPACOM J81 (Joint Innovation and Experimentation Division). The JUSI QRT will develop, test, and validate a concept of employment (CONEMP) for the integration and synchronization of swarming UA performing EA in support of the joint force against an advanced IADS. The JUSI QRT effort is focused on a 2015-2020 timeframe to research and identify previous and ongoing swarm related efforts while building a swarming UA community of interest, concurrent with CONEMP development.

Advanced Integrated Air Defenses and How to Address Them – The Problem

Modern surface-to-air missile (SAM) systems are an integral part of advanced IADS. These IADS are, in turn, integral parts of a potential adversary's networked A2/AD environment. For the purpose of the JUSI QRT effort, IADS refers to a networked system of adversary capabilities (e.g., a series of detection and tracking radars coupled with SAMs) and not specific to one platform (i.e., an IADS on a warship by itself or a specific individual SAM such as an SA-20).

Notional Integrated Air Defense System

The joint forces do not currently have adequate ways to fully plan, integrate, or synchronize the effects delivered by UA swarms. This requires development and testing of a foundational CONEMP offering an effective planning methodology for delivering integrated effects of UA swarms against advanced IADS protecting targets with threat SAM arrays.

The joint force is currently over-reliant on standoff weapons (SOW) and 4th/5th generation strike platforms to address the A2/AD challenge. UA swarms represent a potential additional approach, complementing existing platforms and weapons systems. Despite rapid technical advances in UA swarming development and demonstrations, the joint force lacks a CONEMP for operations requiring UA swarm-delivered effects. The lack of a CONEMP or other supporting documentation hinders requirements development, A2/AD countering, and precludes integration and synchronization with the rest of the joint force.

The Approach – Addressing the Problem

Combat capable and survivable UA with the capability to perform swarming functions are a new but quickly growing aspect of modern warfare. The JUSI QRT will take the first step to characterize, develop, and evaluate a CONEMP for using multiple UA of various sizes to deliver coordinated EA to enable other weapons and platforms (i.e., various types of SOWs, decoys, jammers, and 4th/5th generation platforms) access to counter A2/AD approaches. With the short lifespan of the JUSI QRT—one year—the effort will focus on CONEMP development supported by a series of modeling and simulation (M&S) runs over the course of three test events.

Integrated support by Johns Hopkins University's Applied Physics Laboratory's (JHU/APL) experienced M&S personnel during each of the test events will enable the QRT to gain data collection for the equivalent of hundreds of swarm flights; thus providing a cost saving aspect concurrent with data analysis to support CONEMP development. JHU/APL will provide M&S and analysis of the execution of UA with EA payloads against scenarios developed to test the UA's ability to deliver desired effects against an advanced IADS as part of an A2/AD environment.

The resulting qualitative and empirical data, once analyzed, will enable the JUSI QRT Team to assess findings, conclusions, and recommendations to revise the CONEMP between each test event with JUSI QRT's first test event, which wrapped up on November 20, 2015. Additionally, upon completion of each test event, a Joint Warfighter Advisory Group (JWAG) will be convened to receive test event results—the first JUSI QRT JWAG occurred on December 9, 2015. As the QRT process continues, it will lead to development of a finalized swarming UA CONEMP to provide the link to requirements development and capability integration for the joint force to have a distributed approach to complement existing solutions which focus on 4th/5th generation strike platforms and SOW.

The Way Ahead

At the end of the JUSI QRT, the resulting CONEMP will provide an effective operational context to inform requirements development, roadmaps and, eventually, tactics, techniques, and procedures (TTP) in several areas, including communication, automation, UA, and EA to deliver intended effects. The CONEMP will also serve to help focus future Department of Defense and industry investment. Future considerations related to swarming UA with EA payloads may include development, testing, and validation of TTP for UA with EA payloads. Such TTP would further reinforce the use of swarming UA by empowering the commander to develop standards in the areas of manning, equipping, training, and planning in the joint force. In the interim, the JUSI QRT developed CONEMP will provide planners, trainers, and their supporters with a start point for employment of this capability.

JUSI QRT website: https://intellipedia.intelink.gov/wiki/JUSI

The author would like to thank Lt Col Matthew "Bulldog" Nicholson, Andrew "Wooly" Wolcott, Don Murvin, Brendan "K-PED" Pederson, and Brock Schmalzel for their guidance and feedback during the writing of this article.

1 Martin, Jerome V. Lt Col, USAF, "Victory from Above: Air Power Theory and the Conduct of Operations Desert Shield and Desert Storm," Air University Press, Maxwell Air Force Base, AL, June 1994.

2 "New Delhi could have anti-missile shield by 2014," defencenewsofindia.blogspot.com, August 29, 2011, http://defencenewsofindia.blogspot.com/2011/08/new-delhi-could-have-anti-missile.html#!/2011/08/new-delhi-could-have-anti-missile.html, accessed October 8, 2015.

Mitigating Cosite Interference

by Doug King dking@polezero.com | MPG-Pole/Zero www.polezero.com

Military radios must be able to operate in severe cosite interference environments ***(Figure 1.1 defines cosite interference)***. Cosite interference is a problem faced by many RF and microwave communications platforms; including Unmanned Systems. Military radios often operate in close proximity to additional radios, giving rise to cosite interference. The following article explains the issues associated with military radios operating in close proximity to additional interferers and how Tunable Filters are utilized in real-time applications. Finally, MPG-Pole/Zero's recent advances in mitigating cosite interference are summarized.

Issues associated with military radios operating in close proximity to additional interferers:
Multiple transmitters coupled to antennas in close proximity create a condition called reverse intermodulation, characterized by the coupling of energy from one transmitter into the antenna of another, creating a simultaneous flow of reverse and forward energy. Coupled energy mixes in the nonlinearities in the output network of the transmitter to create an infinite number of intermodulation products. The products are then re-propagated to the collocated receivers, creating products of sufficient level to preclude reception at those frequencies. Thus, a cosite transmitter's output carrier signal can significantly degrade the performance of the receiver.

How Tunable Filters are utilized in cosite interference applications:
The use of a receive filter or filter/LNA cascade such as that introduced in the transmit chain can create "preselection" of the energy from the receive antenna and reduce the relative level of the cosite interferer to the desired signal. Under this condition, the debilitating effect of cosite interference is mitigated by the selectivity of the preselector.

As in the transmit environment, nonlinear effects in the receive chain can be the source of additional cosite interference. The preselection filter serves to minimize the level of the interfering signals prior to the receive nonlinearity, thereby minimizing any resulting products created within the receiver. Pole/Zero designs and tests the filters and LNAs that comprise the cascade filter to ensure that acceptable levels of distortion occur under these conditions.

Greater isolation can effectively be achieved through the use of selective filtering at the transmitter to minimize broadband noise. Selective filtering is applied following the primary noise sources in the transmit signal chain, having the overall effect of lowering the broadband noise without necessitating an increase in antenna isolation.

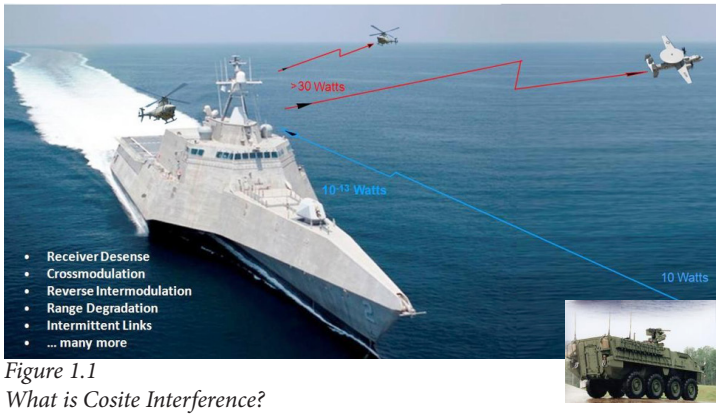


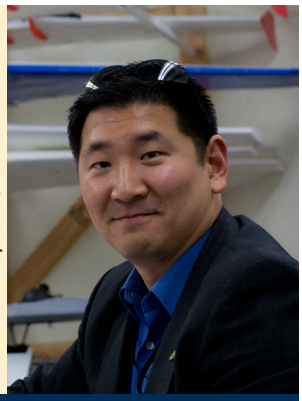
Figure 1.1
What is Cosite Interference?
Cosite Interference occurs when the receiver must operate in the presence of large interfering signals on adjacent channels; while the transmitter noise and spurious signals can artificially raise the system noise floor for collocated (cosite) receivers with the end result of system desensitization and diminished communications range.

For greater selectivity, multiple filters can be placed in cascade with low noise amplifiers (LNAs) for inter-filter isolation and filter loss recovery purposes, followed by a power amplifier designed for efficient operation and low noise output. Further reductions in broadband noise and improved immunity to reverse intermodulation distortion can be achieved with the addition of a high power tunable filter at the output of the PA.

Recent MPG-Pole/Zero tunable filter advances:
MPG-Pole/Zero's recent tunable filter advances for cosite interference mitigation solutions include:

- Highly integrated filter products with significant SWaP reduction, compared to legacy filters, that maintain 5W in-band power over the entire military tactical radio tuning range in single- and dual-channel configurations;
- Miniature SMT bandpass filter options from 30 MHz to 3GHz;
- Narrowband and wideband interference cancelers, some of which do not require an interferer reference, thereby enabling cancellation of off-platform interferers;
- Deep notch filters to create communications channels in wideband, high power signals;
- Miniature, light-weight filter and power amplifier cascades for cosite interference issues inherent in UAV retransmission applications.

Farewell from Dr. Tim Chung, CRUSER Deputy Director:



An essential element of enabling innovation, especially in robotics and unmanned systems, is to embrace continual change and growth. It is in this spirit that we can point to positive examples of change, e.g., in rapid technology development, cultural shifts in public and DoD's perception on unmanned systems, or of operational concepts of employment. Similarly, I can highlight my upcoming departure from the Naval Postgraduate School to serve at DARPA as a positive change, one that recognizes how far we've come (bravo zulu, ARSENL team!) as well as illuminates some of the opportunities of what lies ahead for our ever-thriving CRUSER community. As I've said before, "conversation leads to collaboration, and collaboration leads to innovation," so I look forward to staying actively engaged as a fellow CRUSER member and keeping those conversations going!

STUDENT CORNER

Student: Courtney A. Guy

Title: Satellite Tasking via a Tablet Computer

Curriculum: Mechanical and Aerospace Engineering

Link to Completed Thesis: https://calhoun.nps.edu/handle/10945/47268

Abstract: Tablet computing has the potential to reshape the scope of situational awareness. This is because application developers have derived uses for tablet devices that the original inventors did not intend and could not have imagined. One such application is to provide the ability for the warfighter to directly request aerial images from overhead assets, including unmanned aerial vehicles or satellites. Advancements in mobile technology and network connectivity have helped to overcome the challenges of information delivery, but there remains the challenge of real-time information. This thesis examines the concept of tablet-based information requests for real-time satellite tasking. As a proof-of-concept, a tablet-based application is developed that enables the user to task a satellite system by interacting with a map. Requests are sent and processed by a server application and are then routed to the appropriate asset. Real-time response to the request is emulated using a detailed simulation model of a control moment gyroscope actuated spacecraft. Simulated images and spacecraft attitude errors are used to mimic the data collection process. This information is uploaded to the server for retrieval by the tablet application, thereby completing the request cycle and demonstrating the feasibility of remote satellite tasking using a tablet computer.

Aerospace Tests Drone Detection at Rose Bowl (6 Jan 16)

http://www.aerospace.org/news/highlights/aerospace-tests-drone-detection-at-rose-bowl/ —Laura Johnson

While others were watching football, a dedicated team from The Aerospace Corporation spent New Year's Day testing a method of unmanned aerial vehicle (UAV) detection and takeover outside the Rose Bowl in Pasadena, CA.

With Aerospace's proven testing and evaluation expertise, the team has been looking at ways to use radio frequency (RF) signals to detect, classify, locate, and potentially even take control of UAVs that pose a threat.

Whether it's the hobbyist who inadvertently interferes with firefighting efforts, or a malicious individual trying to harm others, those operating UAVs have the potential to disrupt public safety.

As UAVs continue to proliferate, many entities, including law enforcement, operators of critical infrastructure, and private business owners, may have a need to protect themselves from unwanted UAVs flying in a certain area.

UAVs that are being actively controlled receive an RF signal from their controller. Aerospace has been investigating ways to detect that signal, gather data from it, and/or interfere with it.

While they have had success with their method when they have tested it on Aerospace's campus, demonstrating it in a real-world setting where it might actually be used is critical to proving out the technology.

Coordinating with the Pasadena Police Department, Los Angeles Sheriff's Department, and the Department of Homeland Security, Aerospace was able to conduct several tests at the Rose Bowl, including during the actual game on New Year's Day. This is the type of location that might need protection from UAV threats, and it also poses a challenge since there is a lot of RF activity from television crews, cell phones, walkie talkies, and more.

The team used off-the-shelf hardware, but modified with Aerospace-developed algorithms, to detect and take positive control over a drone. The testing proved that the approach works under real-world conditions and without causing unwanted interference. While this was done with a simulated drone threat and may have been a little less dramatic than the Stanford Cardinal trouncing the Iowa Hawkeyes nearby, the Aerospace team has now collected valuable data that they can use to further refine their algorithms and advance their efforts in counter-UAV technology. Not a bad start to 2016.

photo by Matthew Begert

Librarian's Corner

Hazard From Above: Drone Crash Database [updated January 19, 2016]
https://www.washingtonpost.com/graphics/national/drone-crashes/database/

Hostile Drones: The Hostile Use of Drones by Non-State Actors Against British Targets
http://remotecontrolproject.org/wp-content/uploads/2016/01/Hostile-use-of-drones-report_open-briefing.pdf

Unmanned Aircraft Operations in Domestic Airspace: U.S. Policy Perspectives and the Regulatory Landscape. [CRS report]
http://www.fas.org/sgp/crs/misc/R44352.pdf

CRUSER Calendar

7 Mar (1200 PST) - Monthly Meeting
4 Apr (1200 PST) - Monthly Meeting
details at http://CRUSER.nps.edu